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## HIGH-VOLTAGE ELECTRIC INSULATORS BASED ON WOLLASTONITE

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The possibility of using high-quality finely milled wollastonite in the composition of engineering ceramics is considered. The firing conditions, structure, and physicomechanical parameters of obtained electric insulators are determined.

Engineering ceramics articles of various designations with high dielectric and mechanical parameters are widely used in industry. Composite ceramic materials with the crystalline phase based on wollastonite are becoming more common in the development of electric insulators [1, 2].

The main technological advantages of wollastonite include its good dielectric and physicomechanical parameters, a relatively low firing temperature, a low TCLE, low shrinkage, etc. [3, 4]. However, natural wollastonite mined in the CIS countries contains up to 8% colorant iron and titanium oxides, which restricts its wide use in the production of composite materials and articles.

In this context, research and development of new compositions for electrical-engineering ceramics using finely milled high-quality wollastonite from Uzbekistan, which is produced according to the new method for refining wollastonite ore from metal oxides, holds certain promise. The refining method is based on impact-splitting abrasive grinding with subsequent ultrahigh-frequency treatment and comprehensive electromagnetic separation [5].

The structural specifics and peculiarities of the chemical composition of finely milled wollastonite produced according to the specified technology make it a promising filling agent for ceramic materials intended for electrical engineer-

ing. The present study considers the results of investigation of new compositions for such materials.

Table 1 shows the chemical compositions of wollastonite refined according to the developed technology and other materials used in the production of engineering ceramics. Based on the initial raw materials, we prepared experimental mixtures, whose batch compositions are indicated in Table 2.

The mixtures were dehydrated to residual moisture 22%. Mixture treatment and preparation of samples were carried out by the standard plastic molding technology. Molded samples were dried at temperatures 378 – 383 K for 10 h and then fired under different temperature conditions.

It is found that the sintering temperature for engineering ceramics based on high-quality refined wollastonite concentrate is 1473 – 1523 K. This can be related to its structural and chemical specifics that promote a decrease in the firing temperature and increased mechanic strength: anorthite is

TABLE 2

Material*	Weight content, %, in mixture					
	V-1	V-2	V-3	V-4	V-5	V-6
Angrenskii kaolin	45	40	35	30	25	20
Wollastonite	45	50	55	60	65	70

\* All compositions contained 10% clay and 1% (above 100%) of barium carbonate.

TABLE 1

Material	Weight content, %						
	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	CaO	MgO	K <sub>2</sub> O	Na <sub>2</sub> O
Finely milled high-quality wollastonite*	57.80	8.68	0.22	26.90	0.83	0.90	0.81
Clay	59.01	28.70	0.90	0.72	0.74	1.60	0.10
Angrenskii kaolin	45.58	38.44	0.84	0.90	0.47	0.40	0.38

\* The wollastonite also contained 0.30% SO<sub>3</sub>.

TABLE 3

Parameter	Mixture					
	V-1	V-2	V-3	V-4	V-5	V-6
Moisture, %	20.5	20.8	21.0	22.1	21.5	21.0
Air shrinkage, %	5.25	5.05	5.45	4.98	5.20	5.40
Fire shrinkage, %, at temperature, K:						
1373	7.25	7.45	7.05	7.04	6.22	6.88
1423	8.55	8.35	8.14	8.04	7.82	8.81
1473	10.35	10.25	10.22	9.98	9.55	9.65
1523	12.45	12.32	12.24	12.02	11.98	11.65
Water absorption, %, at temperature, K:						
1373	8.25	9.25	9.55	9.45	9.45	9.35
1423	6.00	5.46	5.24	4.98	4.87	4.78
1473	2.01	2.22	1.98	0.99	0.93	0.91
1523	0.03	0.02	0.03	0.03	0.02	0.02
Compressive strength, MPa, after firing at temperature, K:						
1373	95	96	98	97	93	99
1423	105	115	118	120	129	132
1473	145	132	140	139	141	143
1523	175	172	173	184	186	188
Specific volume resistivity, $\Omega \cdot \text{cm} \times 10^{12}$	3.3	4.3	4.7	4.8	5.0	5.8
Electric strength, kV/mm	26.0	27.0	27.5	28.0	28.5	28.8
Dielectric permittivity	4.5	5.0	5.3	5.2	5.4	5.3
Tangent of dielectric loss angle	0.035	0.050	0.033	0.028	0.029	0.027

formed in firing, making it possible to bring down the firing temperature and accelerate the mullite-forming process, which results in increased mechanical strength and improved dielectric properties of electrical-engineering ceramics. This was corroborated by geno-structural analysis.

Analysis of x-ray patterns of ceramic samples of V-4 mixture fired at different temperatures indicates that quartz and anorthite grains are more clearly expressed at 1423 K, and as the temperature increases, peaks typical of mullite and wollastonite appear in the samples, with a simultaneous presence of quartz and anorthite.

The interplanar distances of mullite ( $d = 0.534, 0.288, 0.254, 0.220$ , and  $0.152$  nm), quartz ( $d = 0.427, 0.334, 0.169$ , and  $0.144$  nm), and anorthite ( $d = 0.294$  and  $0.269$  nm) are registered in samples fired at a temperature of 1523 K. The x-ray patterns of V-5 mixture exhibit a similar picture, i.e., mullite, quartz, anorthite, and wollastonite are present.

As a result of the studies, new mixture compositions were developed for electrical ceramics with a high content of wollastonite and good physicochemical and dielectric properties. High-quality wollastonite significantly improves the physicochemical properties of ceramic materials. Thus, their shrinkage decreases, which is very significant in the production of electrical-engineering ceramics, and the mechanical strength and heat resistance of the material increase. Among the considered compositions, the best parameters were registered in mixtures V-4, V-5, and V-6 (Table 3).

High-voltage insulators ShF-10A were manufactured in industrial conditions on the basis of the developed compositions for engineering ceramics (V-4, V-5, and V-6) using finely milled high-quality wollastonite. Testing demonstrated that the service properties of insulators meet the state standard requirements. Substantial savings can be achieved in this case due to lowering the firing temperature, using relatively cheap local materials, and increasing the electric and mechanical strength of insulators.

Thus, finely milled high-quality wollastonite can be considered a promising filler that improves the properties of ceramics for electrical engineering.

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